TREATMENT OF MUSTARD GAS BURNS*

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The desirability of finding a simple yet demonstrably effective treatment for burns arising from contact with the liquid or vapour form of $\beta\beta^1$-dichloroethyl sulphide led us to consider the problem from the physico-chemical standpoint. A careful study of the literature from 1917 onwards has failed to show any marked advance upon the use of Dakin's solution and bleaching powder ($CaOCl_2$), except that chloramine-T is regarded as more suitable in view of its stability and its non-irritating action.

Very early in the military history of mustard gas it was recognized that its action was most severe on those parts of the human body prone to perspiration. Inexact references to this fact usually mention that mustard gas is lipoid-soluble and that this is the key to the enhanced irritant action. Since human perspiration is an aqueous system, probably an oil-in-water emulsion, the term "lipoid solubility" lacks precision. What is certain is that mustard gas is only slightly soluble in water (possibly 0.07% at 10° C.), but is quite soluble in various organic solvents (notably ligroin, kerosene, petrol, CCl_4, CS_2) and in animal oils and fats. Its solubility in vaseline and paraffin wax is only slight.

Our basic assumption was that mustard gas was taken up by the skin, especially where perspiration was present, by adsorption, as distinct from solubility. This would account for its rapid take-up by an aqueous system. Anything that would increase the surface activity of mustard gas should accelerate its take-up and enhance its vesicant action. As will be seen later, this assumption receives confirmation when the surface-active material lanolin is used.

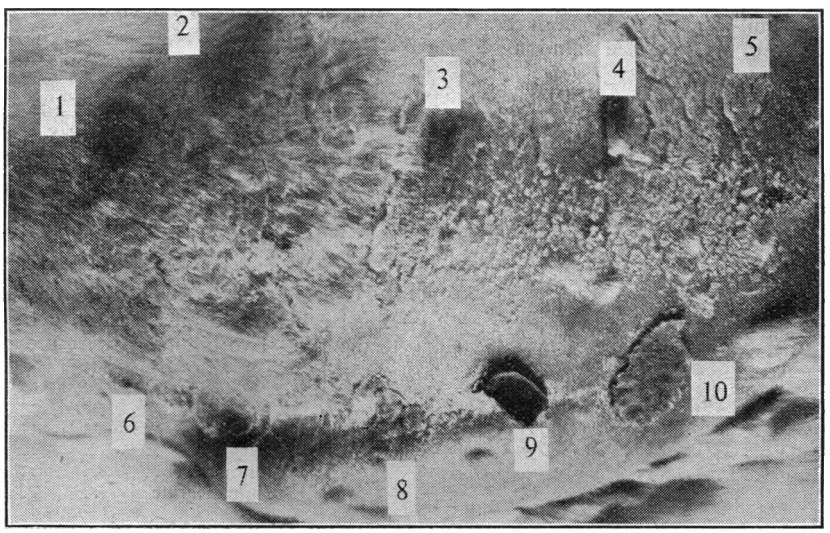

FIG. 1.—Condition of rabbit's back 14 days after application of emulsion for mustard gas burns.

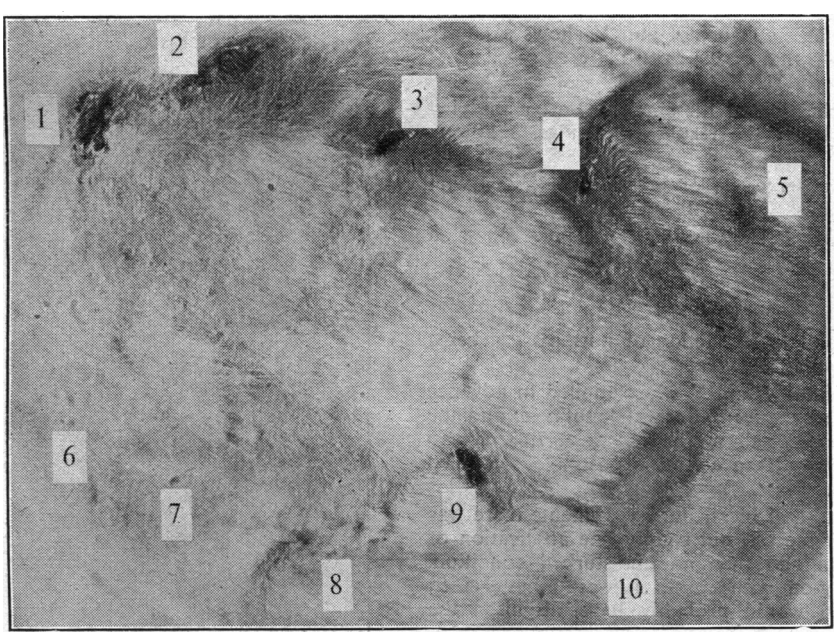

FIG. 2.—Condition of same rabbit 21 days after application. Note complete healing at sites 6, 7, and 8.

Two independent types of adsorption are possible in regard to the take-up of mustard gas by the perspiring skin: (1) adsorption due to the extensive interface presented by the capillary structure of the skin, and (2) adsorption on the fat globules present in perspiration.

For any effective treatment of skin that has been contaminated by mustard gas it is necessary, therefore, to recognize the importance of adsorption as a colloidal phenomenon which can attract mustard gas to a given neutralizing agent. The usual method of swabbing with solvent, followed by an application of a paste of vaseline and bleaching powder (with its essentially short time of contact), and finally by scrubbing with soap and water, has obvious defects when considered from the colloidal point of view.

Swabbing with an organic solvent is recognized as of value. The A.G. Ointment No. 1, however, aims at bringing into intimate chemical reaction two materials which are both insoluble in the common vehicle, vaseline. The limited solubility of mustard gas in vaseline, itself entirely inert chemically and from the capillary-adsorption standpoint, is bad enough, but when this is supposed to lead to a chemical reaction with solid bleaching powder presented as a powder suspended in vaseline the whole basis of the scheme is unsound.

We have used chloramine-T throughout our experiments, with the recognition that its chemical behaviour with mustard gas is quite different from that of bleaching powder. Its permanent stability under our conditions, coupled with its non-irritating action, commended itself. Fundamentally, we have aimed at providing a means of adsorbing and solubilizing mustard gas from the skin and exposing it to the action of chloramine-T both in solution and in suspension at the same time. We have used stable emulsions of carbon tetrachloride and of white spirit in either aqueous or glycerol-saturated solutions of chloramine-T. An inert emulsifying agent was essential and colloidal aluminium hydrate was chosen.

Experiments were made on rabbits. The back of the animal was shaved and then allowed to rest for 24 hours before applying liquid mustard gas from a platinum loop delivering a drop of about 1 mm. diameter. A control drop was always allowed to develop without interruption to serve as a datum for com-

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parison. The animals were photographed after 14 and 21 days respectively.

Two emulsions may be noted from our series:

(X) Glycerol .. .. 100 g. } A
Chloramine-T .. .. .. 18 g. }
Carbon tetrachloride .. .. B

Equal volumes of A and B emulsified. Aluminium hydroxide = 5% of the total emulsion prepared (by weight).

(Y) Water .. .. 100 g. } A
Chloramine-T .. .. 10 g. }
White spirit .. .. B

80 parts of B were emulsified in 20 parts of A (by volume). Aluminium hydroxide = 5% by weight of the total emulsion prepared.

Both emulsions were of the oil-in-water type. Both contained solid chloramine-T in excess of its saturated solution.

A lanolin paste was also prepared:

(Z) Lanolin .. .. 80 g.
Chloramine-T .. .. 20 g.

Intimately rubbed to a smooth cream.

Referring now to Figs. 1 and 2, there are ten points where liquid mustard gas was applied, under conditions as follows:

1. Control (undisturbed)
2. Emulsion Y was applied to the site before mustard
3. „ X „ „ „ „ „ „ „
4. Lanolin Z „ „ „ „ „ „ „
5. Emulsion Y „ „ 2 minutes after the mustard
6. „ „ „ „ 5 „ „ „ „
7. „ X „ „ 2 „ „ „ „
8. „ „ „ „ 5 „ „ „ „
9. Lanolin Z „ „ 2 „ „ „ „
10. „ „ „ „ 5 „ „ „ „

Fig. 1 represents the conditions after 14 days and Fig. 2 after 21 days.

Certain peculiarities are immediately obvious in the general observations which follow:

(*a*) Lanolin Z has expedited eschar formation much beyond that of the control. (See Fig. 1, sites 4, 9 and 10.)

(*b*) Prior application of emulsions X and Y shows a course apparently comparable to that of the control. (See Figs. 1 and 2, sites 2 and 3.)

(*c*) The later the application of the emulsions after applying the mustard drop the better the result. (See Figs. 1 and 2, sites 5, 6, 7, and 8.)

(*d*) The time factor observed in observation (*c*) tallies with that in observation (*a*), sites 9 and 10.

(*e*) Fig. 2, sites 6, 7, and 8, shows complete healing, emulsion X being especially effective.

Discussion

The above results point to the action of mustard gas being a *surface* effect in the first instance.

The failure of emulsions X and Y when applied in advance of the mustard gas, the enhanced effect of lanolin Z. and the unexpected time factor effect shown in sites 5, 6, 7, 8, 9, and 10 all fall into line if a surface action is postulated, coupled with a solubility factor.

It is important to note that in all our experiments there was no rubbing and no washing off, but simply one application of the emulsion or lanolin and then an undisturbed condition. Undoubtedly a washing-off with emulsion would have given even better results and would probably have disguised the peculiar time effects observed.

We believe our results show that there is a threshold or lag period after mustard-gas liquid is applied to the skin, during which time there is the beneficial factor of evaporation of mustard gas from the increased area of its spreading. Accordingly, in sites 5, 6, 7, and 8 we are still in the lag period of skin attack, and, moreover, owing to evaporation the emulsion subsequently applied has less mustard gas to neutralize.

Anything which concentrates mustard gas locally, as by solution, and therefore by inhibiting evaporation, will either speed up skin attack or resist the action of the neutralizing agent. Lanolin Z—sites 4, 9, and 10—supports this view, mustard gas being soluble in lanolin and chloramine-T being insoluble in it. Thus there is a localized retention of mustard gas on the one hand and inability of the neutralizing agent to act on the other. Moreover, the known capillary-active character of lanolin (considered as a colloidal material) would hasten penetration through the skin.

Similarly, sites 2 and 3, though not showing the increased severity of sites 4, 9, and 10, fall into line on the theoretical arguments advanced. Mustard gas is localized by solubility in the continuous phase of the emulsion and its evaporation is retarded. Even more striking results in this direction might be anticipated had the emulsions been of the opposite phase-type —i.e., water-in-oil. An obvious point requiring investigation which arises out of sites 2 and 3 is the *rate* of chemical union between mustard gas and chloramine-T when the reaction takes place in solution.

The above experiments also point to the need for an examination of the actual physico-chemical mechanism by which mustard gas attacks the skin surface.

Incidentally, in light of the above, doubt must be expressed as to the wisdom of instilling a lanolin salve into the eye to counteract mustard gas (see R. Lindsay Rea, *British Medical Journal*, 1939, **2**, 881).

Prophylaxis

The data thus far led us to consider the character of an effective barrier to mustard gas to be applied before exposure to the gas. Two ointments were prepared:

(O′) Glycerol .. .. 50 g.
Chloramine-T .. .. 18 g.
Zinc oxide .. .. 50 g.

(O″) Glycerol .. .. 50 g.
Chloramine-T .. .. 50 g.
Sodium stearate .. .. 2 g.

Ointment O′ was rubbed to a smooth cream; O″ was a gel. Both contained chloramine-T in excess of saturated solution.

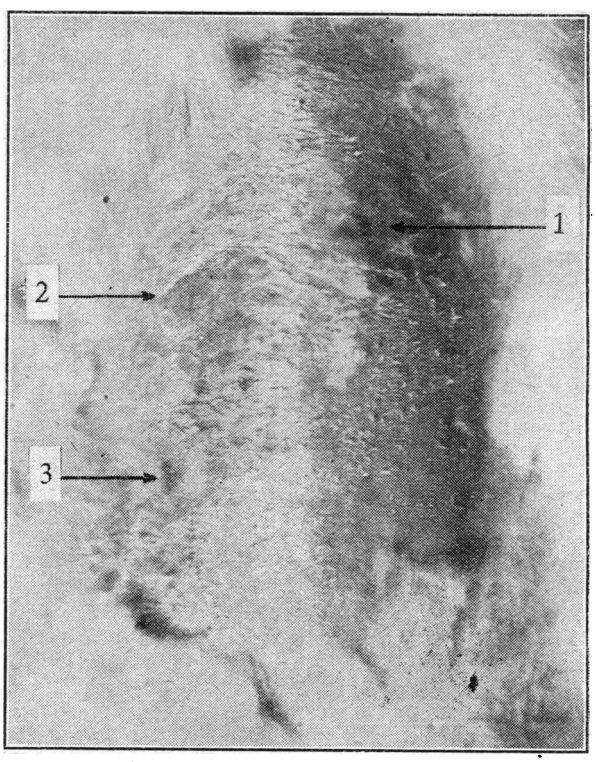

FIG. 3.—Condition of a rabbit's back 8 days after application of ointment as a prophylactic against mustard gas burns.

Referring now to Figs. 3 and 4, site 1 is the control mustard application on the back of a rabbit, 24 hours elapsing after shaving. Sites 2 and 3 had ointment O′ and O″, respectively,

rubbed in, and five minutes later the mustard-gas liquid was applied as previously described, using a platinum loop. Nothing further was done except to put a lint jacket over the rabbit's body about 15 minutes after applying mustard gas to site 3. The photographs were taken 8 and 23 days respectively after application of the mustard gas. *The marked superiority of ointment O′ is shown in site 2.*

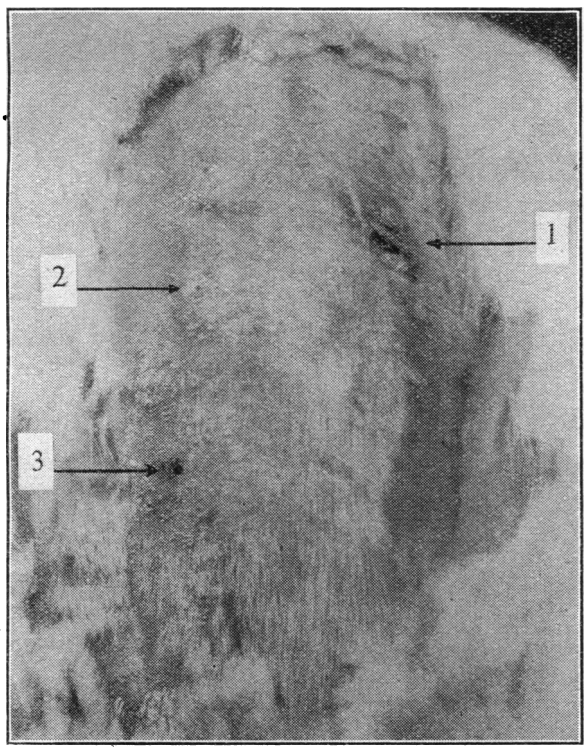

FIG. 4.—Condition of rabbit of Fig. 3 23 days after application of prophylactic ointment. The marked superiority of ointment O′ is shown at site 2.

Zinc oxide was chosen because of its known value in the so-called S.R. lacquers (sulphur-resisting lacquers) used in the internal lining of food cans. During thermal processing, especially of meat foods, sulphur compounds liberated from sulphur-bearing proteins interact with tinplate to form the blue–purple sheen of tin sulphide, often observed inside cans on opening. Ordinary plain (transparent) lacquer still permits such staining, whereas the same lacquer containing very small amounts of zinc oxide in suspension completely avoids sulphur-staining.

Research is obviously required into the possible chemical neutralizing effect of ZnO on mustard gas, the ZnO being suspended in an aqueous solution (or emulsion in saturated aqueous solution) of mustard gas. However, the barrier presented by ointment O′ is now beyond dispute, whatever the actual mechanism of its action.

At the annual general meeting of the Society for Relief of Widows and Orphans of Medical Men, held on May 8, with Dr. R. A. Young, president, in the chair, one vice-president and eight directors were elected to fill the vacancies in the Court of Directors. The annual report showed that the total membership was 282. During 1945 fifty-five widows received relief amounting to £4,837. Each widow over 65 years of age received £75, and those under 65, £60. In addition a Christmas present of £15 was made to each widow. A legacy of £5,000 from the late Dr. Charles Reid, of Stafford, was invested in 2½% Consolidated stock. The invested capital of the society, which is over £140,000, can never be sold and used as income. Many members joined H.M. Forces during the war, and those who have been demobilized are asked to notify the secretary of their present address. Full particulars of membership, which is open to any registered medical man who, at the time of his election, is resident within a twenty-mile radius of Charing Cross, may be obtained from the secretary (11, Chandos Street, Cavendish Square, W.1).

VOLVULUS OF THE SMALL INTESTINE

BY

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Volvulus of the whole or part of the small intestine is said to be exceedingly rare in Europe and America. We have had seven cases—all natives of East Africa—during 1945. Braimbridge, in a personal communication, states that in 25 years of surgical practice in Kenya he has found it the commonest cause of acute intestinal obstruction in the native, occurring in more than half his cases. During 1945 there were 21 admissions with acute intestinal obstruction into the above hospital:

Strangulated inguinal hernia	4
Intussusception (all adolescents or adults)	4
Meckel's diverticulum	1
Bands and adhesions	3
Volvulus of pelvic colon	2
Volvulus of small intestine	7

Symptoms and Signs

The age of an East African is seldom exactly given, for he does not know the year of his birth but only the age group to which he belongs. These patients were variously estimated as being between 20 and 45 years old, and they all complained of abdominal pain, distension, and tympanites. The fact that the majority of cases came to hospital within a few hours of onset indicates the severity of the symptoms. Vomiting, usually regarded as an early and severe symptom, was not a feature, and was recorded in only three of our cases. Rigidity usually masked any visible peristalsis, although this was observed in one case. The abdomen was silent in five. Absolute constipation was not an invariable rule; one of the patients had diarrhoea, and one passed blood and mucus per rectum (he had also partial pelvic colon volvulus). One of the patients (the only female) was eight months pregnant, and her pains were at first thought to be labour pains. In her post-operative convalescence she was delivered of a living child. The following table gives a summary of the seven cases discussed in this report.

Summary of Cases

Case	Sex	Date of Admission	Duration of Symptoms	Interval between Admission and Operation	Type	Result
1	M.	4/1/45	12 hours	1 hour	Whole of S.I.	Recovered
2	M.	24/1/45	1 hour	2 hours	,,	,,
3	M.	14/4/45	36 hours	4 ,,	,,	Died
4	F.	31/5/45	48 ,,	20 ,,	Combined S.I. and L.I.	Recovered
5	M.	26/7/45	4 ,,	18 ,,	Independent S.I. and L.I.	,,
6	M.	6/11/45	4 days	24 ,,	Whole of S.I.	,,
7	M.	12/11/45	11 hours	2½ ,,	,,	,,

Operative Findings

A right paramedian incision was employed for preference, and the purple distended bowel could be seen usually even before opening the peritoneum. The bowel prolapsed through the wound and was reduced in all by exteriorization and rotation until the mesentery lay straight. There were no adhesions or other apparent cause within the abdomen for the rotation, except in one case in which two tapeworms, each 4 ft. (120 cm.) long, were found tied together in a massive knot at the upper end of the jejunum. Owing to the gross distension of the intestine it was found impossible to return the bowel without preliminary evacuation of the contents. In all cases, therefore, a lower loop of intestine was opened, and a rubber tube inserted through the ring of the purse-string suture. In some cases emptying was satisfactory, but in others the tube was soon blocked by undigested food and had to be removed to allow the contents to be emptied. This was done by milking the contents gently out through the enterostomy. Some gas was present, but in the main the bowel contained